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ABSTRACT

Successful commercial use of coal of about 22 percent volatile matter in coking blends containing coal from southern Illinois made it advisable for us to test other medium-volatile coals in similar blends. These eastern coals, which were very fluid in the plastic state, blended well with the less fluid Illinois coals.

Blends containing medium-volatile coals from five seams were coked in our pilot oven. The cokes produced had excellent physical properties. We have concluded that medium-volatile coals of this type may be used advantageously in blends with Illinois coals to produce coke of good metallurgical quality.

INTRODUCTION

Illinois coals have been used continuously in blends for metallurgical coke since the days of World War II. Their use has presented certain problems in blending procedure which have been studied both experimentally and on a commercial scale. Where proper procedures have been developed and followed, the use of Illinois coal has been found advantageous, involving no sacrifice in coke quality and reducing over-all costs.

Illinois coal in the plastic state has relatively low fluidity, especially the No. 6 Coal used for coke production. The Pocahontas Coal normally used in the Chicago and St. Louis areas for blending is also low in fluidity, and when blended with Illinois No. 6, the blend may develop less fluidity than either of the component coals. If the fluidity of the blend falls below a critical value (Reed et al., 1952), the surface of the coke pieces will be rough and the percentage of breeze high. Experience has indicated that such coke is not a good blast furnace fuel.

Illinois No. 5 Coal develops greater fluidity than No. 6 Coal. When 20 percent or more of No. 5 Coal is added to a blend of No. 6 and Pocahontas Coals the fluidity of the blend is usually increased above the critical point, and the structure and size composition of the resulting coke is greatly improved so that it may be used successfully for blast furnace fuel. This type of blend accounts for more than half of the Illinois coal currently used in metallurgical coke plants.

Eastern high-volatile coals may be used in place of Illinois No. 5 Coal to increase the fluidity of such a coal blend. Physical properties of the coke such as size and strength may partly be controlled, therefore, by the characteristics and amount of the third coal added.

Another type of blend in which Illinois coal may be used as a major constituent is now under investigation. During World War II, while experimenting with various low-volatile coals for blending, we found one of the Pocahontas coals contained 22 percent volatile matter and had plastic characteristics very different

from those of the more usual blending coals that contain from 16 to 18 percent volatile matter. The fluidity of this medium-volatile coal was as high as that of some of the high-volatile coals from the eastern field, yet in blends the coal had coking characteristics more nearly like those of a typical low-volatile coal.

Blends of the medium-volatile Pocahontas Coal with Illinois No. 6 produced a satisfactory coke by accepted test procedures. However, as there was no interest at that time in trying such a blend commercially, probably because of a lower coke yield from the medium-volatile coal than from the regular Pocahontas, the matter was dropped. In 1955 interest was revived after modernization of a large medium-volatile Pocahontas mine in Tazewell County, Virginia. This coal had about 22 percent volatile matter and a Gieseler fluidity of 400 to 500 dial divisions per minute. A preliminary study, made in our laboratory, on blends of this coal and Illinois coals indicated that very satisfactory coke could be produced.

Sometime later this medium-volatile coal was tested on a commercial scale in the Chicago area in a blend with Illinois No. 6 and a third coal. Results have not been reported officially, but a blend of this type has continued to be used. We felt, therefore, that further studies should be made with other medium-volatile coals which we believed should blend well with coals from Illinois.

ACKNOWLEDGMENTS

We wish to thank the coal producers and steel companies in both the Illinois and eastern areas that have furnished coals for these tests. We hope that the results obtained will be of value to all those who have helped make this study possible.

PROCEDURE

The movable-wall pilot coke oven in our laboratory has been used since 1953 to evaluate coals in blends having possible commercial application. This oven, 17 inches wide, records wall pressure during carbonization and produces coke closely duplicating that made in commercial ovens. The pilot oven was used to evaluate all blends studied in the investigation.

Samples of coal ranging in volatile matter from 21 to 27 percent were obtained from the Pocahontas, Jewell, Bradshaw, Sewell, and Tiller seams and were blended with No. 5 and No. 6 Coals from southern Illinois. In addition, eastern high-volatile coals were added as a third constituent to some blends in order more nearly to duplicate certain commercial coke practice.

As medium-volatile coal loses a greater percentage of its weight during carbonization than the lower-volatile Pocahontas, it seemed advisable to blend relatively high percentages of medium-volatile coal in order to maintain high yields of coke. We decided, therefore, to experiment primarily with blends containing 40 and 50 percent of the medium-volatile constituent. Other experimental blends containing 25 and 30 percent of certain of these coals in combination with coals from Illinois indicated that the higher percentages were not needed to produce strong cokes.

The same procedure was not used for all tests with the medium-volatile coals. Some blends of medium-volatile and Illinois coals were coked over a wide range of coking time to evaluate the effect of coking rate on coke properties and expansion pressure (Jackman et al., 1958). Other blends were evaluated at one or two normally

Table 1. - Analyses of Coals Used

Coal	M.	Moisture-free analysis V.M.	F.C.	Ash	Sulfur	F.S.I.	Gieseler Fluidity Dial Div. per min.
Illinois No. 6	8.9	38.5	54.4	7.1	0.94	5	37
Illinois No. 5	6.1	37.3	55.5	7.2	1.44	5½	103
Eagle	2.4	36.1	60.0	3.9	0.69	8	6800
E. Kentucky (B and C)	6.0	36.4	56.8	6.8	0.64	7	460
No. 2 Gas	2.0	34.9	58.9	6.2	0.67	9	*
Jewell	3.1	21.3	73.3	5.4	0.58	9	1100
Pocahontas (A)	3.7	22.5	71.2	6.3	0.60	9	*
Pocahontas (B)	5.4	23.4	71.2	5.4	0.64	9	*
Sewell	5.8	23.7	72.8	3.5	0.51	9	*
Bradshaw	3.5	25.7	69.5	4.8	0.67	9	*
Tiller	1.0	27.3	67.5	5.2	0.59	9	*

*Coal swelled out of Gieseler cup.

fast coking rates. Illinois No. 5 and No. 6 Coals were compared in blends with each of the medium-volatile coals tested.

Because the medium-volatile coals were consistently high in fluidity, their blends with Illinois coals were also relatively fluid. This formed the basis of a related investigation in which we showed that Illinois coal could be stockpiled through the summer months, with the usual loss in fluidity due to weathering but without detriment to the coke made from its blends with medium-volatile coal (Jackman et al., 1959).

Average analyses and plastic properties of all coals used in this investigation are shown in table 1.

CARBONIZATION TESTS

In discussing the results of the coking tests, the medium-volatile coals studied have been divided into three groups. Group 1 contains the coals of 21½ to 22½ percent volatile matter (analyses are given on the moisture-free basis throughout this report), group 2 the coals of about 23½ percent volatile matter, and group 3 the coals with volatile matter content of about 25½ to 27½ percent. The samples of the eastern coals were taken by the producers in the size range that would be furnished for metallurgical coke.

The Illinois coals used in blends were obtained from the mines by Survey staff members, and a few samples were taken from cars shipped to metallurgical coke plants. The coals were double-screened sizes between the limits of 3 inches and ¾ inch, which has been the size range recommended for metallurgical coke use. All Illinois coals were wet-washed, some in jigs and some in heavy-media washers.

Eastern high-volatile coals were obtained either directly from the mines or from coke plants in the Chicago area. They were all prepared for metallurgical coke use.

Group 1 ($21\frac{1}{2}$ to $22\frac{1}{2}$ Percent Volatile Matter)

The two coals in group 1 are Jewell and Pocahontas. The Jewell Coal ($1\frac{3}{4}$" x 0) contained about $21\frac{1}{2}$ percent volatile matter, and the Pocahontas ($\frac{3}{4}$" x 0) had a volatile matter content of $22\frac{1}{2}$ percent. This medium-volatile Pocahontas Coal should not be confused with the more commonly used low-volatile Pocahontas Coal.

Both the Jewell and the medium-volatile Pocahontas Coals had a free swelling index (F.S.I.) of 9, and both developed high Gieseler fluidities. Maximum fluidity of the Pocahontas is not shown in table 1 as it swelled out of the Gieseler cup, giving an unrealistic value. Both coals were blended with 50 and 60 percent Illinois coals, and the blends were carbonized at $16\frac{1}{2}$ and $19\frac{1}{4}$ hours coking time. Jewell Coal was blended also with 70 and 75 percent Illinois coals and coked at the faster rate.

In addition to these blends, all of which contained only Illinois and medium-volatile coals, three additional blends were tested, one containing Jewell blended with Illinois No. 6 and Eagle Coals, and the others containing medium-volatile Pocahontas blended with Illinois coals and Eastern Kentucky "B" and "C" Coals.

Results of the group 1 coking tests are shown in tables 2 and 3. Analyses of the blends and cokes produced are found in the Appendix, tables A and B. In these tables the medium-volatile Pocahontas Coal is shown as Pocahontas (A) to distinguish it from the slightly higher-volatile Pocahontas (B) tested in group 2.

Jewell Coal and Pocahontas Coal (A) showed very similar coking properties in blends with Illinois No. 5 and No. 6 Coals. The high fluidity of the medium-volatile coals complemented the relatively low fluidity of the Illinois coals. Blends containing 40 or 50 percent medium-volatile coals and Illinois coals produced cokes ranging in ASTM tumbler stability from 58.8 to 64.3, and in ASTM tumbler hardness from 68.9 to 70.7. Blends of the same coals containing 25 or 30 percent medium-volatile gave cokes with stability ranging from 54.9 to 58.6 and hardness from 67.1 to 67.9. Coke size from all these blends was satisfactory, the 4 by 2 inch size averaging about 68 percent of the total coke at $16\frac{1}{2}$ hours coking time, and 71 percent at $19\frac{1}{4}$ hours. Coke fines were consistently low. The peak expansion pressure ranged from 1.0 to 1.4 pounds per square inch.

Pocahontas (A) was blended also with equal proportions of Eastern Kentucky and Illinois coals and carbonized in $16\frac{1}{2}$ hours. Jewell Coal was blended similarly, but with Eagle instead of the Kentucky coal. The cokes were similar to those that contained only the Illinois and medium-volatile coals, the only apparent difference being a minor reduction in the stability index when eastern high-volatile coals were used.

Group 2 ($23\frac{1}{2}$ Percent Volatile Matter)

Both coals in group 2 contained about $23\frac{1}{2}$ percent volatile matter. One was a Pocahontas coal, called here Pocahontas (B), and the other was Sewell Coal. Both coals had free swelling indices of 9, and high fluidities which could not be measured accurately in the Gieseler plastometer. Both were blended with 50 and 60 percent Illinois coals and coked in $16\frac{1}{2}$ hours. Sewell Coal was blended also with 70 and 75 percent Illinois coals. Additional blends containing equal portions of Illinois No. 6 and West Virginia No. 2 Gas Coals were coked for comparison with those blends in which all the high-volatile coal was from the Illinois field.

Cokes produced from blends with coals of this group were very similar to those produced with the group 1 coals, and all appeared to be satisfactory for blast

furnace fuel. Tumbler stabilities of coke containing the medium-volatile Pocahontas (B) ranged from 55.5 to 58.5, and of coke containing the Sewell Coal from 56.5 to 61.7. Hardness indices of all cokes ranged from 66.1 to 69.8. Regarding coke size, the 4 by 2 inch portion averaged 65.6 percent of the total weight with the medium-volatile Pocahontas blends, and 66.3 percent with the Sewell blends. Coke fines were consistently low, and the expansion pressure never exceeded 1.3 pounds per square inch.

Addition of No. 2 Gas Coal to the blends of Illinois and medium-volatile coals consistently increased the stability index 1 to 2 points and tended to produce slightly heavier coke. Results of the coking tests are shown in tables 4 and 5, and analyses of blends and cokes in tables C and D of the Appendix.

Group 3 ($25\frac{1}{2}$ to $27\frac{1}{2}$ Percent Volatile Matter)

Group 3 also consists of two coals, one from the Bradshaw seam containing about $25\frac{1}{2}$ percent volatile matter and one from the Tiller containing about $27\frac{1}{2}$ percent volatile matter. These coals also had high fluidities. They were blended in the same proportions and coked at the same rate as the other groups, except that no less than 40 percent medium-volatile coal was used in any blend. Results are shown in tables 6 and 7, and analyses of blends and cokes are given in tables E and F of the Appendix.

Blends with the Bradshaw Coal produced cokes with physical properties similar to those of the other cokes described. Stability averaged 58.7 and hardness 68.4. The 4 by 2 inch size averaged 69.3 percent of the total weight, and coke fines remained low. Expansion pressure was consistently below one pound per square inch.

Coke from the blend of 40 percent Bradshaw - 60 percent Illinois No. 6 was rougher in appearance, however, than the other cokes described above. A duplicate test showed the same rough surfaces, and,although this condition was not reflected in the physical tests, we concluded that the upper limit in volatile matter had about been reached for a blend of these two coals. The similar blends of 40 percent Bradshaw with Illinois No. 5 Coal and with Illinois No. 6 and West Virginia No. 2 Gas Coals did not show this rough coke structure.

Tiller Coal was similar to the Bradshaw in that the blend with 60 percent Illinois No. 6 produced rough-appearing coke. Here again the substitution of 30 percent of No. 2 Gas for an equal amount of Illinois coal eliminated the rough appearance.

Tiller coke tended to have lower stability and hardness indices than cokes made from the other coals. Stability ranged from 52.1 to 56.9 and hardness from 64.8 to 66.9, being lowest in the blend with 60 percent Illinois No. 6 Coal. By the usual standards, all of these indices are satisfactory, but the fact that they tend to be lower than those of the other cokes indicates that the upper limit of volatile matter is being approached. It appears, however, that blends containing 50 percent Tiller, or blends of 40 percent Tiller with both Illinois and No. 2 Gas Coals, would produce coke having satisfactory properties.

(Summary and conclusions are given on p. 18)

Table 2. - Coking Tests with Jewell Coal

	50% Ill. No. 6 50% Jewell		50% Ill. No. 5 50% Jewell		60% Ill. No. 6 40% Jewell
	Run 271E	Run 269E	Run 274E	Run 275E	Run 351E
Date of test	3-26-57	3-19-57	4-5-57	4-11-57	5-21-58
Coking time (hr.:min.)	16:30	19:10	16:30	19:15	16:30
Coke Physical Properties					
Tumbler test					
Stability	62.6	62.7	61.7	64.1	60.8
Hardness	70.3	69.2	70.2	70.1	68.9
Shatter test					
+2"	82.9	89.1	78.1	83.1	80.6
+1½"	93.5	95.9	93.5	95.0	92.5
Coke sizing					
+4"	3.3	8.1	3.9	8.7	4.3
4" x 3"	21.9	31.2	21.0	27.9	16.4
3" x 2"	47.0	39.2	51.5	43.9	50.9
2" x 1"	22.0	16.1	18.3	14.7	23.5
1" x ½"	2.0	1.5	1.6	1.7	2.0
-½"	3.8	3.9	3.7	3.1	2.9
Average size (in.)	2.44	2.70	2.49	2.71	2.41
Apparent gravity	0.85	0.84	0.88	0.88	0.84
Coke Yields (% of coal) (Coke at 3% M - coal as received)					
Total coke	73.1	73.8	74.6	74.4	71.4
Furnace (+1")	68.9	69.9	70.7	70.9	67.9
Nut (1" x ½")	1.4	1.1	1.2	1.2	1.4
Breeze (-½")	2.8	2.8	2.7	2.3	2.1
Expansion Pressure					
Lbs. per sq. in.	1.06	1.12	1.0	1.02	1.0
Bulk density (Lbs. per cu. ft.)	52.3	52.3	52.9	52.9	53.7
Operating Data					
Pulverization (-1/8")	86.1	86.6	88.1	87.5	82.5
Flue temp. (°F)	1900	1800	1900	1800	1950
Center coke temp. (°F)	1752	1670	1745	1657	1790

Table 2. - Continued

30% Ill. No. 6 30% Eagle 40% Jewell	70% Ill. No. 6 30% Jewell	45% Ill. No. 6 25% Ill. No. 5 30% Jewell	50% Ill. No. 6 25% Ill. No. 5 25% Jewell
Run 358E	Run 411E	Run 382E	Run 381E
6-24-58	1-27-59	10-14-58	10-10-58
16:30	16:30	16:30	16:30
	Coke Physical Properties		
58.5	58.6	57.5	54.9
68.9	67.9	67.1	67.2
75.2	78.4	81.7	77.9
91.2	92.8	93.6	92.1
2.5	3.0	3.6	3.7
16.5	16.0	17.7	18.3
51.5	48.8	51.1	49.7
24.6	26.0	22.0	22.2
2.0	2.3	2.3	2.5
2.9	3.9	3.3	3.6
2.37	2.33	2.41	2.41
0.86	0.79	0.82	0.82
	Coke Yields (% of coal) (Coke at 3% M - coal as received)		
72.6	69.9	70.1	69.7
69.1	65.5	66.2	65.5
1.4	1.6	1.6	1.7
2.1	2.8	2.3	2.5
	Expansion Pressure		
1.1	1.2	1.2	1.0
53.1	53.5	53.6	54.1
	Operating Data		
84.2	81.5	80.4	77.4
1950	1950	1950	1950
1808	1788	1790	1798

Table 3. - Coking Tests with Pocahontas Coal (A)

	50% Ill. No. 6 50% Pocahontas(A)		50% Ill. No. 5 50% Pocahontas(A)		30% Ill. No. 6 30% E. Kentucky 40% Pocahontas(A)
	Run 287E	Run 286E	Run 279E	Run 278E	Run 291E
Date of test	6-6-57	6-4-57	5-2-57	4-30-57	6-27-57
Coking time (hr.:min.)	16:30	19:15	16:30	19:15	16:30
Coke Physical Properties					
Tumbler test					
Stability	61.1	64.3	61.2	64.0	55.7
Hardness	70.6	69.6	70.6	70.7	68.5
Shatter test					
+2"	74.6	83.5	78.7	80.1	76.4
+1½"	92.8	96.2	93.9	94.1	91.8
Coke sizing					
+4"	4.6	4.6	3.5	8.0	4.4
4" x 3"	17.8	24.3	19.5	29.7	22.7
3" x 2"	49.5	46.6	51.0	41.0	45.4
2" x 1"	22.6	18.1	21.3	16.1	21.9
1" x ½"	1.7	1.5	1.4	1.3	1.8
-½"	3.8	4.9	3.3	3.9	3.8
Average size (in.)	2.43	2.52	2.45	2.69	2.48
Apparent gravity	0.85	0.82	0.87	0.87	0.86
Coke Yields (% of coal) (Coke at 3% M - coal as received)					
Total coke	72.1	72.5	73.0	73.6	71.3
Furnace (+1")	68.2	67.9	69.6	69.9	67.3
Nut (1" x ½")	1.2	1.1	1.0	0.9	1.3
Breeze (-½")	2.7	3.5	2.4	2.8	2.7
Expansion Pressure					
Lbs. per sq. in.	1.1	1.3	1.1	1.1	-
Bulk density (Lbs. per cu. ft.)	53.5	53.5	53.5	53.6	51.1
Operating Data					
Pulverization (-1/8")	85.4	86.4	88.3	89.5	88.5
Flue temp. (°F)	1900	1800	1900	1800	1900
Center coke temp. (°F)	1685	1660	1738	1615	1742

Table 3. - Continued

	60% Ill. No. 6 40% Pocahontas(A)		60% Ill. No. 5 40% Pocahontas(A)		30% Ill. No. 5 30% E. Kentucky 40% Pocahontas(A)
	Run 288E	Run 289E	Run 281E	Run 280E	Run 282E
Date of test	6-11-57	6-13-57	5-9-57	5-7-57	5-15-57
Coking time (hr.:min.)	16:30	19:15	16:30	19:15	16:30
Coke Physical Properties					
Tumbler test					
Stability	58.8	61.5	59.5	62.1	56.6
Hardness	69.5	69.5	69.8	69.8	69.5
Shatter test					
+2"	77.0	83.8	79.4	81.9	71.0
+1½"	93.0	94.7	92.7	94.5	90.2
Coke sizing					
+4"	2.5	5.7	4.9	9.4	5.4
4" x 3"	18.4	24.2	19.3	26.6	23.4
3" x 2"	46.7	47.4	47.9	41.4	39.0
2" x 1"	27.1	16.9	22.8	17.0	27.2
1" x ½"	1.5	1.7	1.8	1.6	1.2
-½"	3.8	4.2	3.3	4.0	3.8
Average size (in.)	2.35	2.56	2.46	2.67	2.46
Apparent gravity	0.84	0.82	0.87	0.85	0.89
Coke Yields (% of coal) (Coke at 3% M - coal as received)					
Total coke	70.6	71.1	72.1	72.5	72.1
Furnace (+1")	67.0	67.0	68.5	68.4	68.5
Nut (1" x ½")	1.0	1.2	1.2	1.2	0.9
Breeze (-½")	2.6	2.9	2.4	2.9	2.7
Expansion Pressure					
Lbs. per sq. in.	1.0	1.4	1.0	1.0	1.05
Bulk density (Lbs. per cu. ft.)	53.2	53.0	52.7	52.4	53.6
Operating Data					
Pulverization (-1/8")	83.8	86.0	88.4	86.0	85.1
Flue temp. (°F)	1900	1800	1900	1800	1900
Center coke temp. (°F)	1685	1662	1724	1650	1750

Table 4. - Coking Tests with Pocahontas Coal (B)

	50% Ill. No. 6 50% Pocahontas(B)	50% Ill. No. 5 50% Pocahontas(B)	25% Ill. No. 5 25% No. 2 Gas 50% Pocahontas(B)
	Run 333E	Run 337E	Run 335E
Date of test	3-11-58	3-25-58	3-18-58
Coking time (hr.:min.)	16:30	16:30	16:30
Coke Physical Properties			
Tumbler test			
Stability	57.4	57.0	58.5
Hardness	67.9	67.9	69.0
Shatter test			
+2"	68.9	80.5	73.0
+1½"	90.8	92.5	90.6
Coke sizing			
+4"	1.7	1.5	2.5
4" x 3"	17.2	14.9	18.3
3" x 2"	48.5	49.4	48.4
2" x 1"	27.6	29.3	25.9
1" x ½"	2.0	2.1	2.1
-½"	3.0	2.8	2.8
Average size (in.)	2.33	2.28	2.37
Apparent gravity	0.87	0.895	0.88
Coke Yields (% of coal) (Coke at 3% M - coal as received)			
Total coke	70.7	72.5	73.2
Furnace (+1")	67.1	69.0	69.5
Nut (1" x ½")	1.4	1.5	1.6
Breeze (-½")	2.2	2.0	2.1
Expansion Pressure			
Lbs. per sq. in.	0.97	0.99	1.17
Bulk density (Lbs. per cu. ft.)	54.3	53.7	54.5
Operating Data			
Pulverization (-1/8")	86.2	89.7	85.8
Flue temp. (°F)	1950	1950	1950
Center coke temp. (°F)	1790	1789	1808

Table 4. - Continued

	60% Ill. No. 6 40% Pocahontas(B)	30% Ill. No. 6 30% No. 2 Gas 40% Pocahontas(B)
	Run 334E	Run 336E
Date of test	3-13-58	3-20-58
Coking time (hr.:min.)	16:30	16:30
Coke Physical Properties		
Tumbler test		
Stability	55.5	56.9
Hardness	66.9	68.5
Shatter test		
+2"	71.0	74.5
+1½"	91.0	90.6
Coke sizing		
+4"	2.4	1.6
4" x 3"	14.8	18.5
3" x 2"	49.0	49.2
2" x 1"	28.6	25.2
1" x ½"	2.0	2.4
-½"	3.2	3.1
Average size (in.)	2.30	2.35
Apparent gravity	0.85	0.88
Coke Yields (% of coal) (Coke at 3% M - coal as received)		
Total coke	69.7	72.4
Furnace (+1")	66.1	68.5
Nut (1" x ½")	1.4	1.7
Breeze (-½")	2.2	2.2
Expansion Pressure		
Lbs. per sq. in.	0.86	1.08
Bulk density (Lbs. per cu. ft.)	53.9	53.8
Operating Data		
Pulverization (-1/8")	85.7	84.8
Flue temp. (°F)	1950	1950
Center coke temp. (°F)	1790	1802

Table 5. - Coking Tests with Sewell Coal

	50% Ill. No. 6 50% Sewell	60% Ill. No. 6 40% Sewell	60% Ill. No. 5 40% Sewell
	Run 353E	Run 354E	Run 416E
Date of test	6-3-58	6-5-58	2-13-59
Coking time (hr.:min.)	16:30	16:30	16:30
Coke Physical Properties			
Tumbler test			
Stability	60.3	59.0	61.3
Hardness	69.2	66.1	69.8
Shatter test			
+2"	79.9	76.2	82.9
+1½"	92.5	90.1	93.5
Coke sizing			
+4"	2.7	3.3	1.8
4" x 3"	19.5	21.2	13.7
3" x 2"	49.4	46.9	51.3
2" x 1"	23.3	22.8	28.4
1" x ½"	2.0	1.6	1.8
-½"	3.1	4.2	3.0
Average size (in.)	2.41	2.43	2.29
Apparent gravity	0.82	0.80	0.84
Coke Yields (% of coal) (Coke at 3% M - coal as received)			
Total coke	70.4	69.8	71.5
Furnace (+1")	66.8	65.8	68.0
Nut (1" x ½")	1.4	1.1	1.3
Breeze (-½")	2.2	2.9	2.2
Expansion Pressure			
Lbs. per sq. in.	1.11	0.98	1.24
Bulk density (Lbs. per cu. ft.)	53.4	50.6	53.1
Operating Data			
Pulverization (-1/8")	85.7	82.6	82.6
Flue temp. (°F)	1950	1950	1970
Center coke temp. (°F)	1830	1830	1827

Table 5. - Continued

25% Ill. No. 6 25% No. 2 Gas 50% Sewell	30% Ill. No. 6 30% No. 2 Gas 40% Sewell	45% Ill. No. 6 25% Ill. No. 5 30% Sewell	50% Ill. No. 6 25% Ill. No. 5 25% Sewell
Run 361E	Run 362E	Run 386E	Run 385E
7-3-58	7-8-58	10-27-58	10-23-58
16:30	16:30	16:30	16:30
	Coke Physical Properties		
61.7	60.3	59.4	56.5
69.5	68.1	68.9	68.1
81.1	77.8	71.1	77.9
92.4	94.3	90.8	91.5
3.2	2.8	3.9	2.7
19.3	14.9	14.5	13.8
51.8	52.9	45.7	49.4
20.5	24.0	29.7	27.3
2.1	2.3	2.4	2.8
3.1	3.1	3.8	4.0
2.45	2.36	2.30	2.28
0.84	0.84	0.80	0.81
	Coke Yields (% of coal) (Coke at 3% M - coal as received)		
73.4	71.6	70.6	70.0
69.6	67.8	66.2	65.2
1.5	1.6	1.7	2.0
2.3	2.2	2.7	2.8
	Expansion Pressure		
1.23	1.30	1.12	1.00
53.0	53.9	53.7	53.2
	Operating Data		
89.2	81.7	81.1	79.1
1950	1950	1950	1950
1805	1808	1789	1795

Table 6. - Coking Tests with Bradshaw Coal

	50% Ill. No. 6 50% Bradshaw	50% Ill. No. 5 50% Bradshaw	25% Ill. No. 6 25% No. 2 Gas 50% Bradshaw
	Run 305E	Run 326E	Run 307E
Date of test	10-29-57	2-6-58	11-5-57
Coking time (hr.:min.)	16:30	16:30	16:30
	Coke Physical Properties		
Tumbler test			
Stability	61.2	59.7	57.7
Hardness	69.2	68.5	68.5
Shatter test			
+2"	81.0	78.3	79.0
+1½"	93.4	94.3	93.8
Coke sizing			
+4"	3.7	2.7	3.9
4" x 3"	15.8	16.4	19.3
3" x 2"	53.7	52.6	53.0
2" x 1"	23.0	23.8	18.7
1" x ½"	1.2	1.7	1.6
-½"	2.6	2.8	3.5
Average size (in.)	2.42	2.39	2.48
Apparent gravity	0.86	0.87	0.87
	Coke Yields (% of coal) (Coke at 3% M - coal as received)		
Total coke	70.0	72.4	72.6
Furnace (+1")	67.4	69.1	69.0
Nut (1" x ½")	0.8	1.2	1.1
Breeze (-½")	1.8	2.1	2.5
	Expansion Pressure		
Lbs. per sq. in.	0.90	0.79	0.98
Bulk density (Lbs. per cu. ft.)	54.5	55.2	53.6
	Operating Data		
Pulverization (-1/8")	89.1	83.5	81.4
Flue temp. (°F)	1950	1950	1950
Center coke temp. (°F)	1828	1781	1830

Table 6. - Continued

	60% Ill. No. 6 40% Bradshaw	60% Ill. No. 5 40% Bradshaw	30% Ill. No. 6 30% No. 2 Gas 40% Bradshaw
	Run 306E	Run 328E	Run 308E
Date of test	10-31-57	2-14-58	11-7-57
Coking time (hr.:min.)	16:30	16:30	16:30
	Coke Physical Properties		
Tumbler test			
Stability	57.7	58.0	58.0
Hardness	67.6	68.6	68.2
Shatter test			
+2"	79.5	79.0	75.0
+1½"	92.0	91.9	92.0
Coke sizing			
+4"	3.0	1.6	5.0
4" x 3"	23.1	16.0	22.7
3" x 2"	44.0	54.3	45.2
2" x 1"	25.9	23.0	22.2
1" x ½"	1.2	2.1	1.4
-½"	2.8	3.0	3.5
Average size (in.)	2.45	2.36	2.50
Apparent gravity	0.86	0.88	0.86
	Coke Yields (% of coal) (Coke at 3% M - coal as received)		
Total coke	69.2	71.1	71.9
Furnace (+1")	66.4	67.5	68.3
Nut (1" x ½")	0.8	1.5	1.0
Breeze (-½")	2.0	2.1	2.6
	Expansion Pressure		
Lbs. per sq. in.	0.84	0.95	0.90
Bulk density (Lbs. per cu. ft.)	54.1	54.9	54.0
	Operating data		
Pulverization (-1/8")	87.6	83.0	86.5
Flue temp. (°F)	1950	1950	1950
Center coke temp. (°F)	1830	1799	1824

Table 7. - Coking Tests with Tiller Coal

	50% Ill. No. 6 50% Tiller	50% Ill. No. 5 50% Tiller	25% Ill. No. 6 25% No. 2 Gas 50% Tiller
	Run 340E	Run 338E	Run 342E
Date of test	4-3-58	3-27-58	4-10-58
Coking time (hr.:min.)	16:30	16:30	16:30
Coke Physical Properties			
Tumbler test			
Stability	56.9	56.1	54.7
Hardness	66.6	66.6	66.8
Shatter test			
+2"	73.1	77.4	75.3
+1½"	92.3	91.6	92.9
Coke sizing			
+4"	2.2	3.9	2.6
4" x 3"	17.3	15.9	15.9
3" x 2"	52.7	48.1	52.4
2" x 1"	22.5	27.1	23.8
1" x ½"	1.9	1.9	2.2
-½"	3.4	3.1	3.1
Average size (in.)	2.38	2.36	2.36
Apparent gravity	0.85	0.89	0.89
Coke Yields (% of coal) (Coke at 3% M - coal as received)			
Total coke	71.7	73.7	73.5
Furnace (+1")	67.9	70.2	69.6
Nut (1" x ½")	1.4	1.3	1.6
Breeze (-½")	2.4	2.2	2.3
Expansion Pressure			
Lbs. per sq. in.	0.91	0.85	0.98
Bulk density (Lbs. per cu. ft.)	53.1	54.6	53.3
Operating Data			
Pulverization (-1/8")	89.7	87.9	89.8
Flue temp. (°F)	1950	1950	1950
Center coke temp. (°F)	1749	1788	1819

Table 7. - Continued

	60% Ill. No. 6 40% Tiller	60% Ill. No. 5 40% Tiller	30% Ill. No. 6 30% No. 2 Gas 40% Tiller
	Run 341E	Run 339E	Run 345E
Date of test	4-8-58	4-1-58	4-22-58
Coking time (hr.:min.)	16:30	16:30	16:30
Coke Physical Properties			
Tumbler test			
Stability	54.5	52.1	56.2
Hardness	64.8	65.3	66.9
Shatter test			
+2"	75.3	76.7	74.1
+1½"	91.5	91.4	90.7
Coke sizing			
+4"	3.9	2.0	3.0
4" x 3"	11.8	14.3	15.8
3" x 2"	52.5	50.4	51.3
2" x 1"	26.3	27.8	24.5
1" x ½"	2.1	2.2	2.3
-½"	3.4	3.3	3.1
Average size (in.)	2.32	2.29	2.36
Apparent gravity	0.84	0.86	0.87
Coke Yields (% of coal) (Coke at 3% M - coal as received)			
Total coke	69.7	71.7	72.6
Furnace (+1")	65.9	67.8	68.7
Nut (1" x ½")	1.4	1.5	1.6
Breeze (-½")	2.4	2.4	2.3
Expansion Pressure			
Lbs. per sq. in.	0.99	0.97	1.07
Bulk density (Lbs. per cu. ft.)	52.9	52.2	52.8
Operating Data			
Pulverization (-1/8")	88.5	85.6	85.4
Flue temp. (°F)	1950	1950	1950
Center coke temp. (°F)	1819	1780	1835

SUMMARY AND CONCLUSIONS

The successful commercial use of coals of about 22 percent volatile matter in blends containing an appreciable quantity of Illinois coal made it desirable to evaluate medium-volatile coals from several sources in blends of this type. These medium-volatile coals are more highly fluid in the plastic state than are low-volatile Pocahontas Coals, and they blend well with the less fluid coals from Illinois.

Six medium-volatile coals from five seams were studied in blends with the Illinois No. 5 and No. 6 Coals. In addition, other blends containing medium-volatile, Illinois, and eastern high-volatile coking coals were carbonized and the cokes were evaluated.

Cokes made from these blends appeared to have good metallurgical properties. Strength indices were consistently high, and the major portion of the coke was in the 4 by 1 inch size range. The percentage of furnace size coke tended to be high and the yield of coke fines was consistently low. Expansion pressure during carbonization never exceeded a safe limit, even with 50 percent of medium-volatile coal in the blend. Excellent coke was made with as much as 70 to 75 percent of Illinois coal in the blend with the medium-volatile coals of $21\frac{1}{2}$ to $23\frac{1}{2}$ percent volatile matter. The tests made indicate that less Illinois coal should be used as the volatile matter in the eastern coal approaches $27\frac{1}{2}$ percent, which was the highest volatile content of any medium-volatile coal studied in this series of tests.

We have concluded that, due to their high fluidity and strongly coking properties, medium-volatile coals of the type studied may be used advantageously in blends with the coals of Illinois to produce coke of good metallurgical quality.

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APPENDIX

Analytical and Coking Results

Table A. - Analytical Data for Experimental Coke Runs Shown in Table 2

Run No.		M.	Moisture-free analysis V.M.	F.C.	Ash	Sulfur	F.S.I.
		50% Illinois No. 6 50% Jewell					
271E	Blend	3.8	30.2	63.3	6.5	0.84	7½
	Coke		1.0	90.4	8.6	0.64	
269E	Blend	4.2	29.6	63.9	6.5	0.85	8
	Coke		1.5	89.9	8.6	0.66	
		50% Illinois No. 5 50% Jewell					
274E	Blend	3.0	28.8	64.7	6.5	1.30	9
	Coke		1.1	90.0	8.9	1.07	
275E	Blend	3.1	29.5	63.8	6.7	1.56	8½
	Coke		1.5	89.7	8.8	1.14	
		60% Illinois No. 6 40% Jewell					
351E	Blend	5.8	31.4	62.1	6.5	0.77	7½
	Coke		1.2	89.9	8.9	0.62	
		30% Illinois No. 6 30% Eagle 40% Jewell					
358E	Blend	4.0	31.1	63.1	5.8	0.71	9
	Coke		1.2	90.9	7.9	0.61	
		70% Illinois No. 6 30% Jewell					
411E	Blend	5.7	32.6	60.8	6.6	0.77	7
	Coke		1.3	89.8	8.9	0.59	
		45% Illinois No. 6 25% Illinois No. 5 30% Jewell					
382E	Blend	4.7	33.7	59.3	7.0	1.16	6½
	Coke		1.2	89.0	9.8	0.94	
		50% Illinois No. 6 25% Illinois No. 5 25% Jewell					
381E	Blend	5.7	33.8	58.7	7.5	1.15	7
	Coke		1.5	88.1	10.4	0.92	

Table B. - Analytical Data for Experimental Coke Runs Shown in Table 3

Run No.		M.	Moisture-free analysis V.M.	F.C.	Ash	Sulfur	F.S.I.
		50% Illinois No. 6 50% Pocahontas(A)					
287E	Blend	5.5	30.3	62.9	6.8	0.75	8½
	Coke		2.5	88.5	9.0	0.68	
286E	Blend	5.1	30.5	62.7	6.8	0.81	8½
	Coke		2.3	88.6	9.1	0.69	
		50% Illinois No. 5 50% Pocahontas(A)					
279E	Blend	3.8	29.4	63.7	6.9	1.01	9
	Coke		1.4	89.3	9.3	0.89	
278E	Blend	4.0	29.7	63.6	6.7	1.01	8½
	Coke		1.8	88.8	9.4	0.88	
		30% Illinois No. 6 30% E. Kentucky 40% Pocahontas(A)					
291E	Blend	4.6	32.0	61.1	6.9	0.69	7½
	Coke		2.5	87.9	9.6	0.65	
		60% Illinois No. 6 40% Pocahontas(A)					
288E	Blend	5.6	32.1	61.2	6.7	0.76	8
	Coke		2.2	88.3	9.5	0.67	
289E	Blend	5.6	32.2	61.1	6.7	0.79	8
	Coke		1.8	88.4	9.8	0.66	
		60% Illinois No. 5 40% Pocahontas(A)					
281E	Blend	4.1	31.1	62.2	6.7	1.06	9
	Coke		1.5	88.9	9.6	0.91	
280E	Blend	4.2	31.1	62.0	6.9	1.14	8
	Coke		1.8	88.8	9.4	0.95	
		30% Illinois No. 5 30% E. Kentucky 40% Pocahontas(A)					
282E	Blend	3.3	31.4	62.1	6.5	0.82	8
	Coke		1.3	89.7	9.0	0.77	

Table C. - Analytical Data for Experimental Coke Runs Shown in Table 4

Run No.		M.	Moisture-free analysis V.M.	F.C.	Ash	Sulfur	F.S.I.
		50% Illinois No. 6 50% Pocahontas(B)					
333E	Blend	5.1	30.5	63.4	6.1	0.75	8½
	Coke		1.3	90.4	8.3	0.64	
		50% Illinois No. 5 50% Pocahontas(B)					
337E	Blend	3.8	30.1	64.0	5.9	1.01	9
	Coke		1.2	90.8	8.0	0.86	
		25% Illinois No. 5 25% No. 2 Gas 50% Pocahontas(B)					
335E	Blend	3.0	29.9	64.2	5.9	0.73	9
	Coke		1.2	91.0	7.8	0.62	
		60% Illinois No. 6 40% Pocahontas(B)					
334E	Blend	5.2	31.7	62.3	6.0	0.78	8½
	Coke		1.2	90.4	8.4	0.62	
		30% Illinois No. 6 30% No. 2 Gas 40% Pocahontas(B)					
336E	Blend	3.0	30.6	63.6	5.8	0.73	9
	Coke		1.1	91.0	7.9	0.65	

Table D. - Analytical Data for Experimental Coke Runs Shown in Table 5

Run No.		M.	Moisture-free analysis V.M.	F.C.	Ash	Sulfur	F.S.I.
		50% Illinois No. 6 50% Sewell					
353E	Blend	5.6	31.4	63.6	5.0	0.69	8½
	Coke		1.4	91.5	7.1	0.51	
		60% Illinois No. 6 40% Sewell					
354E	Blend	7.2	32.8	61.6	5.6	0.72	7½
	Coke		1.4	90.8	7.8	0.53	
		60% Illinois No. 5 40% Sewell					
416E	Blend	4.2	31.4	63.2	5.4	1.13	8
	Coke		1.3	91.2	7.5	0.95	
		25% Illinois No. 6 25% No. 2 Gas 50% Sewell					
361E	Blend	4.2	30.4	64.6	5.0	0.61	8½
	Coke		1.4	91.8	6.8	0.47	
		30% Illinois No. 6 30% No. 2 Gas 40% Sewell					
362E	Blend	3.8	31.3	63.6	5.1	0.61	8½
	Coke		0.9	92.0	7.1	0.50	
		45% Illinois No. 6 25% Illinois No. 5 30% Sewell					
386E	Blend	4.8	32.7	60.9	6.4	1.08	7½
	Coke		1.2	89.7	9.1	0.96	
		50% Illinois No. 6 25% Illinois No. 5 25% Sewell					
385E	Blend	5.3	33.3	60.2	6.5	1.13	6½
	Coke		1.1	89.6	9.3	0.98	

Table E. - Analytical Data for Experimental Coke Runs Shown in Table 6

Run No.		M.	Moisture-free analysis V.M.	F.C.	Ash	Sulfur	F.S.I.
			50% Illinois No. 6 50% Bradshaw				
305E	Blend	3.8	31.3	62.9	5.8	0.82	8
	Coke		1.1	90.4	8.5	0.69	
			50% Illinois No. 5 50% Bradshaw				
326E	Blend	4.0	31.3	62.9	5.8	1.21	9
	Coke		1.2	91.0	7.8	0.95	
			25% Illinois No. 6 25% No. 2 Gas 50% Bradshaw				
307E	Blend	3.9	31.2	62.7	6.1	0.78	8½
	Coke		1.7	90.1	8.2	0.61	
			60% Illinois No. 6 40% Bradshaw				
306E	Blend	5.2	33.1	60.9	6.0	0.89	7½
	Coke		1.5	89.6	8.9	0.74	
			60% Illinois No. 5 40% Bradshaw				
328E	Blend	4.0	32.6	61.2	6.2	1.30	9
	Coke		1.2	90.6	8.2	1.04	
			30% Illinois No. 6 30% No. 2 Gas 40% Bradshaw				
308E	Blend	4.0	33.1	61.4	5.5	0.76	8
	Coke		1.3	90.6	8.1	0.67	

Table F. - Analytical Data for Experimental Coke Runs Shown in Table 7

Run No.		M.	Moisture-free analysis V.M.	F.C.	Ash	Sulfur	F.S.I.
		50% Illinois No. 6 50% Tiller					
340E	Blend	4.6	32.6	61.4	6.0	0.75	9
	Coke		1.0	90.6	8.4	0.60	
		50% Illinois No. 5 50% Tiller					
338E	Blend	3.4	31.7	62.4	5.9	0.92	9
	Coke		1.4	90.5	8.1	0.76	
		25% Illinois No. 6 25% No. 2 Gas 50% Tiller					
342E	Blend	3.1	31.7	62.3	6.0	0.70	8½
	Coke		1.0	90.9	8.1	0.58	
		60% Illinois No. 6 40% Tiller					
341E	Blend	5.6	33.7	60.1	6.2	0.77	9
	Coke		0.9	90.5	8.6	0.63	
		60% Illinois No. 5 40% Tiller					
339E	Blend	4.0	32.9	61.0	6.1	1.04	9
	Coke		1.0	90.5	8.5	0.81	
		30% Illinois No. 6 30% No. 2 Gas 40% Tiller					
345E	Blend	3.0	32.2	61.8	6.0	0.70	9
	Coke		0.9	90.8	8.3	0.59	

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